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AWARD NUMBER DAMD17-97-1-7192

TITLE: Development of High Performance Displays for Mammography

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REPORT DATE: June 1998

TYPE OF REPORT: Annual

PREPARED FOR: Commander
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
June 1998

3. REPORT TYPE AND DATES COVERED
Annual (12 May 97 - 11 May 98)

4. TITLE AND SUBTITLE
Development of High Performance Displays for Mammography

5. FUNDING NUMBERS
DAMD17-97-1-7192

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of Arizona
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This research program is directed toward the development of markedly improved high performance displays, designed to enhance diagnosis in digital mammography. The activities of the first year centered around the development of instrumentation for the experimental investigation of the novel cathodoluminescent materials and substrates with respect to their potential for use in electronic displays.

(1) A demountable display tube was designed, ordered and constructed. It permits investigation of samples of the novel cathodoluminescent materials and their respective substrates with respect to characteristic display performance measures.

(2) A probe was constructed which permits measurement of luminance and contrast of luminescent samples in the presence of glare.

(3) A compact display evaluation system was developed which permits measurement of pertinent display characteristics

(4) A contract was established with the University of California at Berkely to deposit CsI on substrates provided by the U of Arizona for investigation in the demountable display tube.

14. SUBJECT TERMS
Breast Cancer
Cathode Ray Tube (CRT), Cesium Iodite (CsI)
Soft Copy Display

15. NUMBER OF PAGES
13

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

FOREWORD

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Hans Rodewig 06/10/98

PI - Signature Date

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I. Introduction:

This research project is concerned with digital mammography and its thrust to improve on diagnostic performance using soft copy display compared to "state of the art" radiographic film-light box mammography. An essential component of digital mammography that will be critical to its success, is the high performance display from which diagnosis is to be carried out. The research is aimed at the development of a new generation of vastly improved high performance displays to meet the needs of mammography.

CRTs have already become an integral part of the diagnostic radiology department. Efforts are underway to investigate the suitability of high-resolution CRTs for primary diagnosis by the radiologist [1]. In fact the US Armed Forces have begun a program designed to accelerate the proliferation of digital imaging methods including primary diagnosis using softcopy displays. The Medical Diagnostic Imaging Support (MDIS) program is a Department of Defense Project to implement filmless radiology at military medical facilities [2] and there are studies emerging from Universities [3]. Initial results appear to be encouraging, even though serious questions remain. A recent workshop on problems of softcopy displays for use in digital mammography, organized by the Office of Women's Health [4] testifies that the medical community as well as the Federal Government is focussing its attention on the problem of finding adequate softcopy displays for primary diagnosis. Problems addressed during this workshop included optimization of the display-observer interface and standardization.

CRT displays have been undergoing intense development over the past 10-15 years and research on new display devices as well as development of new display devices is underway [5,6]. A specialty of our research program at the University of Arizona is to provide a quantitative measure of display performance [7,8, 9]. We have measured many of the best displays available over the past 5 years. This has led to the realization that their performance is far from ideal and significant improvement is unlikely if the traditional CRT structure, the faceplate and the deposition of the granular phosphor in a binder on this faceplate, is not changed. It is the objective of this research project to investigate means to improve softcopy displays

II. Body of the Report:

Development of the instrumentation for the experimental investigation

A. Demountable display tube

Central to our experimental program is a demountable display tube. It was acquired from the Teltron Corporation in Birdsboro, PA.

The objective of the demountable display tube is to permit analysis of a variety of luminescent samples. The particular features of the demountable display tube are discussed with reference to Fig. 1. Contrary to a conventional sealed off display tube, the demountable display tube is connected to a vacuum pump to permit evacuating the tube after a luminescent sample has been

placed in the sample holder and the faceplate has been put in place. After evaluation of the sample's luminescent characteristics, the pressure in the tube is slowly increased until normal air pressure is reached in order to permit removal of the faceplate for the exchange of the luminescent sample under test with another one.

It is crucial for the operation and particularly for the lifetime of the electron gun, that care is taken not to expose the thermionic cathode of the electron gun to air during the change of luminescent samples. Exposure to air will drastically reduce the electron emission of the cathode. Such catastrophic reduction of the electron emission of the thermionic cathode can be avoided by filling the electron gun section of the tube with an inert gas such as nitrogen (N_2) during the change of the samples.

The demountable test station consists of the following parts

- **Drive electronics module** with the following features.
  - Capable of displaying a 640 x 480, 800 x 600, 1024 x 768 or a 1280 x 1024 line monochrome image on the target.
  - Adjustable anode voltage, focus voltage, image size, image centering, image brightness and image contrast
  - Meters for anode voltage and screen current.

- **Two vacuum test chambers**, 3 inch (76.2 mm) round with vacuum port at the end where the electron gun is; with the following features:
  - Ultra-high resolution electron guns capable of 0.0007 inch (0.018 mm) linewidth with standard cathodes sealed to the vacuum test chambers provided; high durability thoriated electron guns will be made available when completed.
  - Holding fixtures for the luminescent samples to fit in the 3 inch (76.2 mm) diameter front end
  - Two 3 inch (76.2 mm) diameter polished glass plates with antireflection coating on both sides to serve as display tube faceplates
  - Substrates for the luminescent samples
    - Fiber-optic disks, 6-8 micron fiber size, N.A. 0.66, polished both sides
    - Clear glass disks, polished on both sides
    - Circular copper meshes with 750 to 1000 lines/inch

- **Computer system**
  - IBM compatible computer (without monitor) that mates with above drive electronics module
  - Various test patterns for evaluation of luminescent samples are available

- **One sealed of 3 inch (76.2 mm) display tube to test the drive electronics**
  - With P1-phosphor
  - With same electron gun as in demountable vacuum chamber.

Unfortunately substantial delays occurred during the fabrication process, mainly due to overcrowding of the vendor's workload but also due to inclusion of features, which initially were not included in the original design. As a result, the system was not delivered until the end of May 1998. However initial tests indicate that the system is working significantly better than had been expected from the outset.

The system is presently with our consultant Donald Quimette at the University of Connecticut for the purpose of interfacing the demountable tube to a vacuum system and placing the whole structure into a mechanical holder. It will be delivered to the University of Arizona in the middle of June.

Adjustment of the work schedule at the U of A should assure that these delays do not interfere with the goals of the overall program. Also, in reviewing the delays in the delivery schedule of the vendor one has to keep in mind that we had substantial difficulties in obtaining a vendor for the specific demountable display system.

B Special probe for the accurate determination of display luminance and contrast ratio

One of the biggest problems in the conventional CRT-display technology is the loss of contrast due to scatter of light (1) in the faceplate, (2) in the phosphor layer and (3) in the interior of the glass envelope. Therefore the measurement of the amount of glare for a CRT is very important. However this measurement is very difficult owing to the fact that most commonly used equipment such as detectors with lenses affect the measurement itself. This is because light is either scattered in the lens itself, or light is scattered or reflected of the instrument surfaces back into the surface the luminance of which is to be measured.

It is for this reason that a probe was designed and constructed which will minimize the amount of interference in the measurement of luminance ratios in the presence of high luminance surround. It is shown schematically in Fig. 2. Basically it consists of a relatively long tube of approximately 10 mm inside diameter, with a set of 4 discs with a center hole of 1 mm diameter, precisely aligned along the tube axis. The inside of the tube including the disks are anodized black. These disks serve as baffles, causing light rays which enter the tube under an angle with respect to the main axis to be absorbed, and permitting only light which enters the tube along the tube's main axis to reach the detector.

This probe was constructed and will be evaluated shortly.

After the construction of this probe it was learned that a similar probe was designed and evaluated for the same purpose of precisely measuring display contrast ratios by Flynn et. al. at the University of Michigan [10].

C. Display evaluation system

Another important development affecting this research program was the development of a CRT-evaluation system based on a CCD camera. The original CRT evaluation system at the University of Arizona was based on mechanically scanning a photomultiplier-lens-slit assembly in small steps across the active area of the CRT.

Performing CRT evaluation with such mechanical scanning instrumentation however is fairly time consuming. Furthermore, it could lead to errors because of mechanical vibrations. It was therefore decided to develop a new CRT evaluation system, based on a CCD camera. Such systems have become fairly popular recently [11]. In fact, the system which was developed at the U of Arizona during the first year of this research project has become quite compact due to the fact, that an interface between a CCD camera and a Laptop computer could be incorporated.

The CCD camera is based on a high performance CCD with the following features:

- o 2048 x 2048 pixels of 0.0068 mm x 0.0068 mm size
- o cooled to -25 ^{0}C.
- o read-out noise at 500 K-pixels/sec read-out is about 40 electrons
- o digitization to 14 bits
- o A variety of 35 mm type photographic Nikon lenses as well as microscope lenses are available to permit operating with a variety of optical magnifications to achieve resolution on the CRT to well below 0.020 mm

Software is available on the PCs for

- o data correction
- o data analysis
  Fourier Transforms (for noise power spectra and MTF measurements); evaluation of modulation and any kind of image analysis;
- o display of results

Fig. 3 shows the system in use: The CCD camera images a relatively small portion of the CRT under test, and the test images are displayed on the Laptop's display; they are analyzed by the software available on the Laptop.

D. Placing a contract with the University of California at Berkely for the preparation of CsI samples.

A major portion of time was spent to place a contract with the University of California at Berkely for the preparation of CsI samples to be evaluated in the demountable system described above. Of particular interest were questions of intellectual properties. However now all problems have been resolved and we are ready to receive the samples.

III Conclusion

The experimental equipment necessary to investigate the novel cathodoluminescent samples has been developed and is ready to go. The development of the equipment is late, however changes in the work schedule at the U of Arizona will off set these delays and assure that these delays do not interfere with completion of the goals of the overall program.

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V. Figures

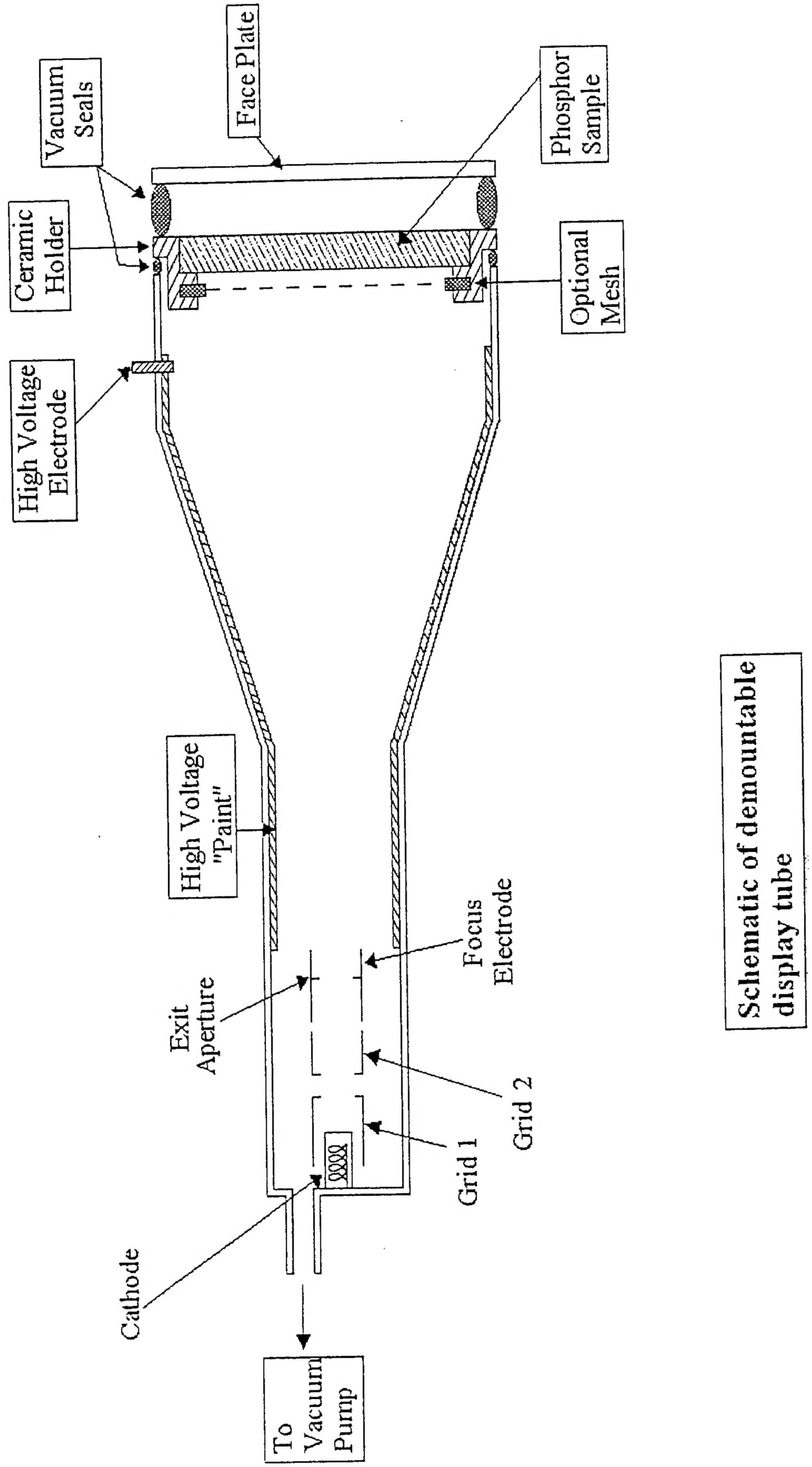

Fig. 1: Schematic of demountable display tube

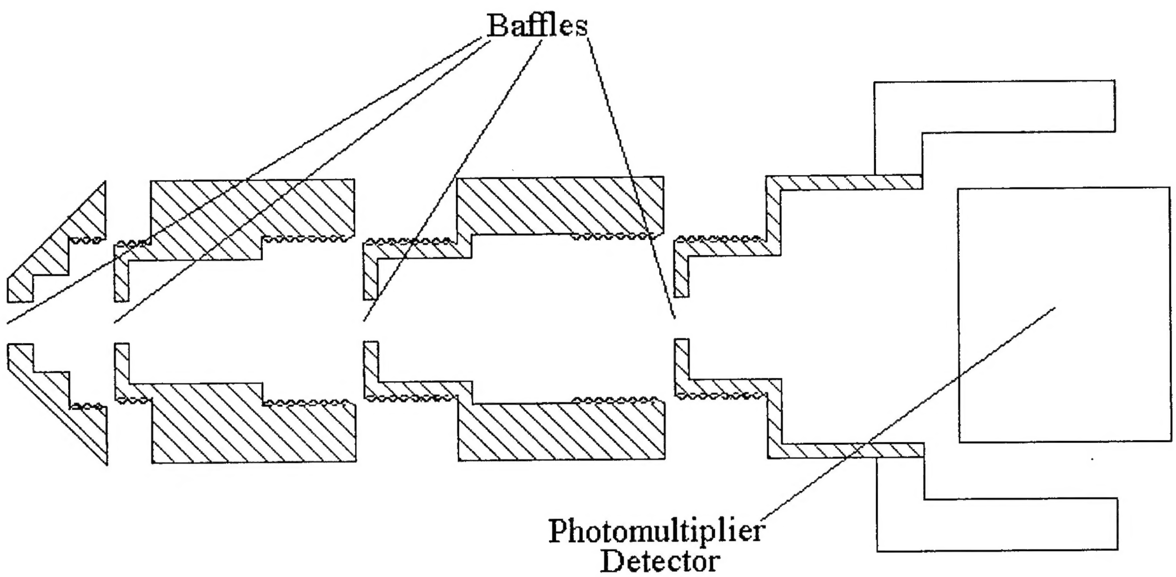

Fig. 2. Schematic of probe for the accurate measurement of a CRT's contrast ratio

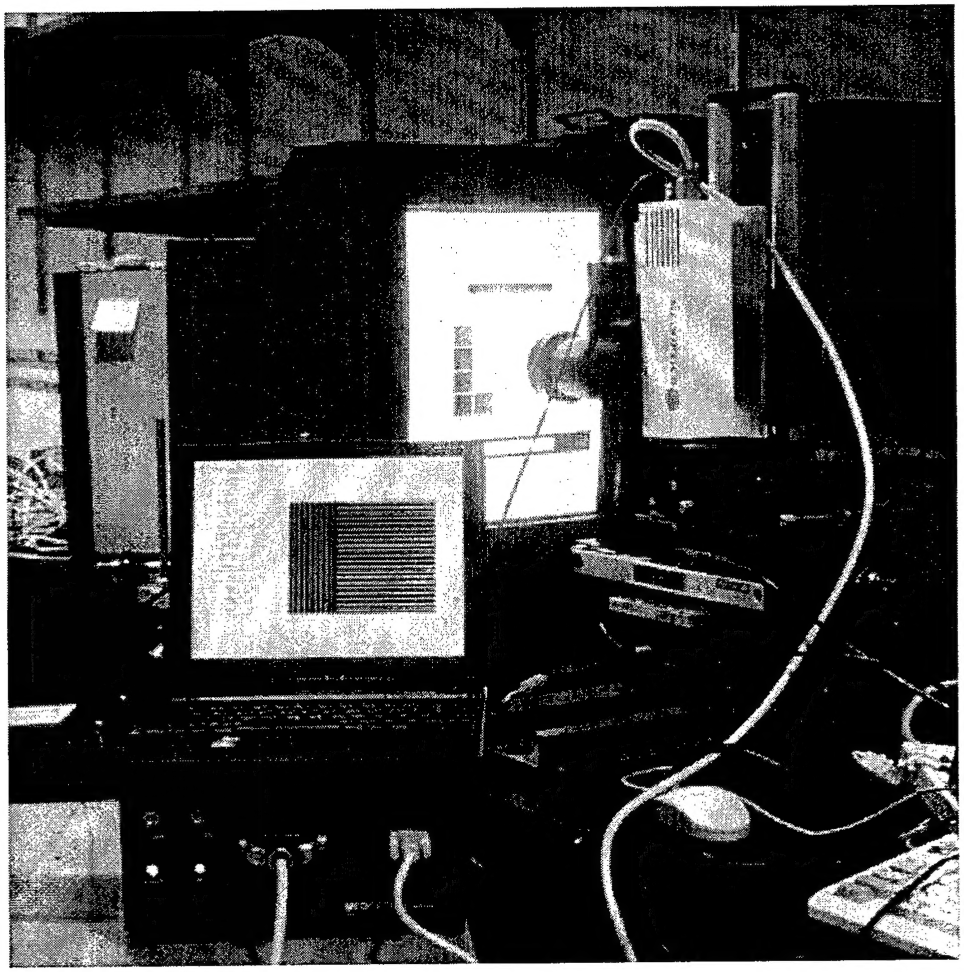

Fig. 3 New compact CRT evaluation system at the U of Arizona, based on a CCD camera controlled by a Laptop computer